1.2 What is High-Speed Rail?

High-speed rail[3] is a group of passenger transportation technologies that is generally considered to be most appropriate for intercity trips in the 100- to 500-mile range. High-speed rail technology options range from upgraded but conventional steel-wheel-on-rail systems such as Amtrak's Metroliner service between Boston and Washington, D.C. to systems using magnetically-levitated vehicles.

The provision of high-speed rail service involves advanced technology or significant upgrades to conventional signaling and control systems, track or guideway, and the vehicles themselves. Maximum commercial operating speeds for high-speed rail range from about 125 to 300 mph. Three categories of high-speed rail technology were analyzed and considered as part of this study:

- **High speed (HS)** – HS systems are improved versions of traditional steel-wheel-on-rail technology and can operate at maximum speeds of 125 to 150 mph (200-250 kph). HS systems typically operate on existing rail rights-of-way that have been upgraded through some combination of sub-grade, track, and signal improvements; the addition of grade-crossing protection or grade separation; and the construction of passing sidings. "Tilt train" vehicles are often utilized in this speed range to permit higher operating speeds when traversing curves in the alignment. Although existing HS services have maximum grades of 2 percent or less, HS technology is capable of gradients of up to 5 percent.

- **Very high speed (VHS)** – Very high-speed systems travel at top speeds of 180 to 220 mph (290-350 kph), using a new generation of steel wheel-on-rail technology. To achieve these operating speeds, VHS systems require very straight route alignments that are completely grade-separated and electrified. The current maximum gradient maintained by a VHS service is 3.5 percent; however, 4 percent grades are planned for future services and this technology is capable of achieving grades up to 5 percent.

- **Magnetic levitation (Maglev)** – Maglev systems use electromagnetic force to levitate and propel trains along a fixed guideway at operating speeds of 200 to 310 mph. This technology is capable of maintaining grades of up to 10 percent. There are no high-speed Maglev systems in revenue service. Both the German and Japanese governments have sponsored Maglev technology development. The German technology has been approved for commercial use in the Hamburg-Berlin Corridor while the Japanese technology is still being tested. At this time, the Hamburg-Berlin project is projected to begin revenue service in 2006.

[3] This group of technologies is also sometimes referred to as High-Speed Ground Transportation (HSGT).

1.2.1 High-Speed Rail in Europe and Japan

High-speed rail systems are common in Europe and Japan (see Figure 1.1). Two of the most well known systems are the Japanese Shinkansen and the French TGV. A brief description of these systems will illustrate how high-speed rail has been successful in these countries.

The Japanese Shinkansen [4]

The first Japanese "bullet trains" began service more than 30 years ago on the densely populated corridor between Tokyo and Osaka. At the time, high-speed trains were Japan's answer to a critical shortage of both rail and highway capacity. Today, the high-speed Shinkansen network consists of four lines, totaling over 1,150 miles. In addition to the Tokaido line between Tokyo and Osaka, the Tohoku line extends east from Tokyo to Morioka, the Sanyo line serves the far west between Osaka and Hakata, and the Joetsu line runs north from Tokyo to Niigata. There is also a spur off the Tohoku line from Fukushima to Yamagata.

Japan has a population of over 120 million in a relatively small land area (130,400 square miles). Most of Japan's population resides in cities arrayed in linear fashion along the coastal plain, an arrangement amenable to efficient rail service. Approximately 30 million, 16 million, and 8.5 million live within approximately 30 miles of central Tokyo, Osaka, and Nagoya, respectively. Railway stations are typically located in dense city centers and are highly accessible by a variety of modes. Japanese highways are capacity-constrained and subject to high tolls, and fuel costs are about triple of that in the United States.

Service on the Shinkansen lines is characterized by very high frequency combined with short distances of about 20 miles between stations. The Tokaido Shinkansen operates on a 1-7-3 pattern with hourly departures of one two-stop, seven limited-stop, and three local trains. A typical weekday schedule offers over 100 trains departing from Tokyo towards Osaka at headways of as little as three minutes. A total of 282 trains operate daily on the Tokaido line; when the Sanyo line is included, the number rises to 401. The maximum speed on the Tokaido and Sanyo lines is 169 mph. The Tohoku and Joetsu lines generally run at a maximum speed of 172 mph. These high frequencies, fast speeds, and short distances between stations are accommodated by multiple unit electric rail vehicles.

The above factors combine to give high-speed rail advantages in terms of service frequency, reliability, safety, and cost. Although air service competes with rail, the Shinkansen captures a large share of travel under 458 miles in distance. The Shinkansen trains carry nearly 300 million people every year (781,000 every day). The busiest line is the Tokaido, which carries 360,000 passengers per day, followed by the Tohoku (190,000 passengers), the Sanyo (158,000 passengers), and the Joetsu (73,000 passengers). Given its strong competitive position, the Shinkansen is able to charge relatively high fares (for example, the current one-way express fare between Tokyo and Osaka, a distance of 345 miles, is about $125 for a reserved seat).

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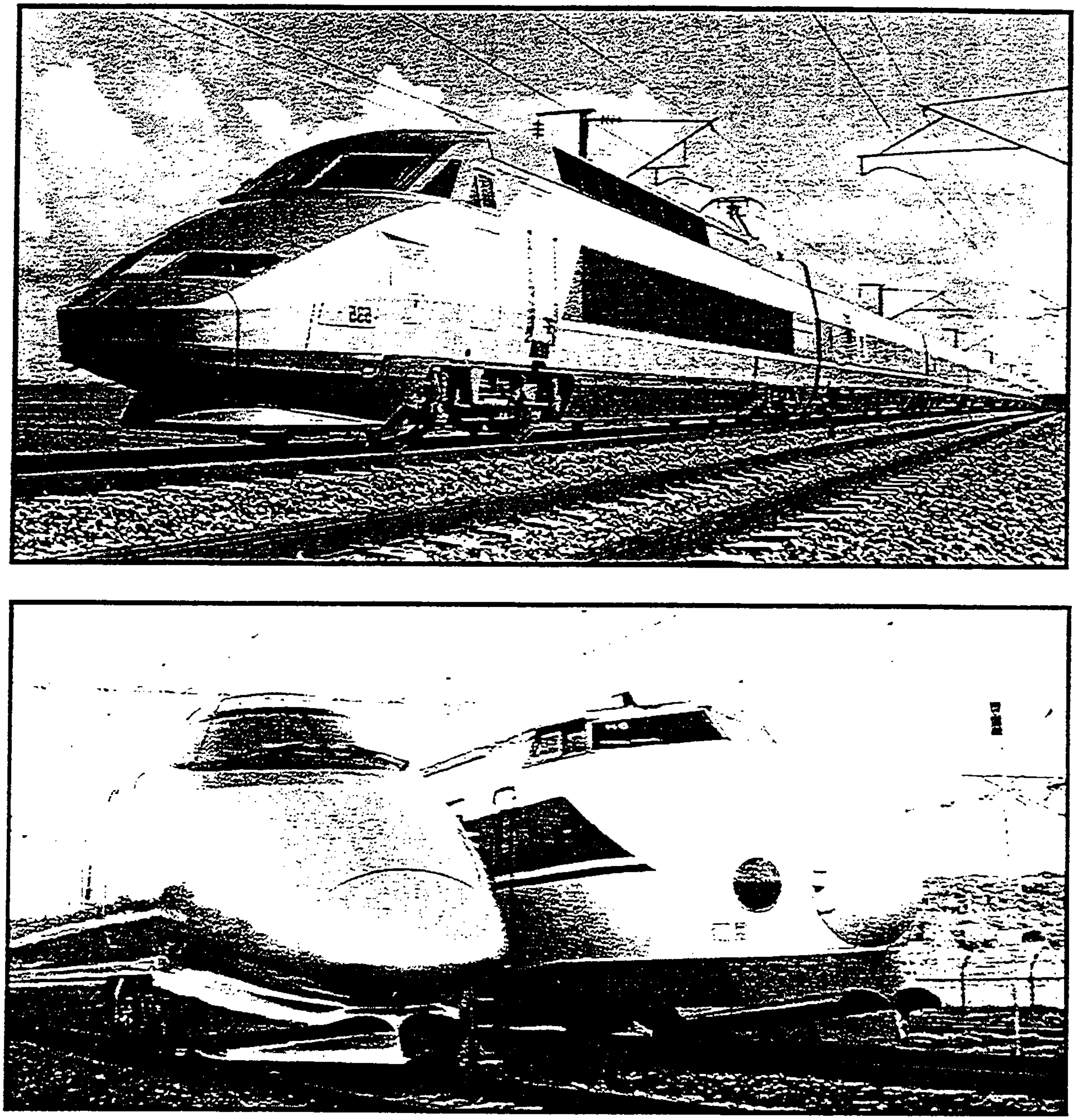
[4] This section draws upon Taniguchi (1992), Central Japan Railway Company (1995), Okada (1996), and the 1996 railway schedule published by the JR Group.

Figure 1.1 Typical High-Speed Rail Technologies



Two examples of the VHS technology group: the French TGV Atlantique (top) and the Japanese Shinkansen Series 400 and Series 200.

Source: Parsons Brinckerhoff.

While the Shinkansen lines have attracted substantial patronage, construction costs have been high due to topographic and geologic features. Nevertheless, according to JR Central, the Tokaido Shinkansen recouped its construction costs in just seven years. This feat was accomplished in a corridor that now accounts for 36 percent of Japan's population and 48 percent of the country's gross domestic product. As of 1985, the Tokaido and Sanyo lines were showing revenue to expenditure ratios of 2.36 and 1.37, while the Tohoku and Joetsu lines were still in deficit finance. These latter two lines, however, were not opened until 1983.

The French TGV[5]

The original line in France's Train à Grande Vitesse (TGV) network was the Sud Est, opened in two stages in 1981 and 1983 and serving the Paris-Lyon Corridor and points south. Since then, France has proceeded with a network of high-speed lines centered around Paris. Newer TGV lines include the Atlantique (1989), serving Brittany and Bordeaux, and the TGV Nord (1993), serving the northern city of Lille and international service to London and Brussels. An "interconnect" line allows high-speed service to bypass Paris. Plans for additional TGV lines connecting to Germany, Italy, and Spain are underway.

TGV service is provided not only over specially-engineered high-speed lines, but over "conventional" rail lines used by other rail services as well. Thus, the reach of the TGV service is far greater than the length of the new high-speed lines alone. For example, while the TGV Sud Est includes only 334 miles of new high-speed lines, it also operates over an additional 1,118 miles of conventional line to serve destinations such as Marseille, Nice, and Rouen. Upon completion of the interconnect line east of Paris, the French National Railways (SNCF) has 795 miles of new high-speed lines integrated into a network of over 3,480 miles and 136 stations. Given the concentration of population in the Paris metropolitan region (the 1990 population was some 9.3 million) and the extent of the TGV service network, it is safe to say that the majority of the French population is served by the TGV.

Different variations of the steel-wheel-on-rail, electric traction powercars and passenger cars are used for the various lines and services. These include the TGV Atlantique configuration, which currently holds the world record for commercial train speed at 320 mph. Normal maximum operating speeds on dedicated high-speed lines range from 168 mph on the Sud Est to 186 mph on the Atlantique and Nord lines. On conventional lines, the maximum operating speed is 137 mph.

In terms of patronage, revenues, and profitability, the TGV has been characterized as a success by the French national railway company. Although recent annual patronage figures are not available, the TGV Sud Est has carried 230 million passengers since its inception. The TGV Atlantique has carried 100 million passengers and the TGV Nord has carried eight million. Total TGV ridership for 1994 was 45 million passengers.

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[5]This section draws upon Société Nationale des Chemins de Fer Français (SNCF) (1995) and Streeter (1992).

The TGV has been highly competitive with air and highway travel. In particular, a market decrease in airline patronage between Paris and Lyon was observed upon introduction of the TGV Sud Est. A slowdown in the growth of traffic on highways directly competing with the TGV lines has also been reported. The TGV is said to capture 90 percent of the market for city pairs separated by a journey time of between one and two hours. For travel times of three hours, the TGV captures over half the intercity market. It is worth pointing out, however, that the TGV's past success was achieved under a highly-regulated domestic air market and in the context of Europe's higher fuel prices and extensive highway tolling.

On the international front, the TGV-like Eurostar trains presently hold a 40 percent share of the total air and rail market on the Paris-London route. This trip takes three hours from station to station on a route using the TGV Nord line and the Channel Tunnel.

Looking at the financial performance of the TGV, the Sud Est and Atlantique lines appear to have been financially profitable. According to SNCF, the Sud Est line returned a $382 million net profit, after operations, maintenance, depreciation, and finance costs were taken into account in 1991. The Atlantique's operating profit in 1991 is said to have been $157 million. TGV trainsets have also been running between Madrid and Seville, Spain, since 1992. New lines on which TGV trainsets are due to operate are under construction in Belgium between the French border and Brussels, and in Korea between Seoul and Pusan.

1.2.2 High-Speed Rail in the United States

Currently, Amtrak's Metroliner service between New York City and Washington, D.C. is the only rail service in the United States that can be characterized as high-speed rail. The hourly Metroliner trains make the 226 mile trip in under three hours at speeds up to 125 mph. The Metroliner service is highly competitive, capturing 45 percent of the endpoint New York-to-Washington intercity travel[6]. This level of service was achieved by a $2.3 billion federal investment program approved in 1976, which included track upgrading, new locomotives, improved signaling and communications systems, and removal of all highway grade crossings[7]. With the acquisition of tilt trains and electrification between New York City and Boston, this level of service will soon be extended throughout the entire Northeast Corridor.

The Northeast Corridor is the only intercity corridor to receive significant federal support in the United States. Although there have been numerous studies and efforts to build other high-speed rail systems in the U.S., none have been constructed. Most notably were attempts to privately finance systems in California (Los Angeles-San Diego, 1984); Nevada/California (Las Vegas-Los Angeles, 1987); Florida (Tampa-Orlando-Miami, 1984-1986); and Texas (Texas Triangle: Dallas-Houston and San Antonio, 1989-94) – in each case, financing was withdrawn. Currently, a revived public/private effort in Florida with

[6]Reistrup (1996).

[7]Transportation Research Board (1991).

the state and a consortium led by Fluor Daniel and the French TGV manufacturer (GEC Alsthom/SNCF/Bombardier) has begun the preliminary engineering/environmental clearance process. The $4.8 billion, 320-mile high-speed rail line (Tampa-Orlando-Miami) is planned to be fully operational by 2006.

Recognizing the potential of high-speed rail to play an important role in certain intercity corridors, the federal government has sponsored legislation for study, research, and development of high-speed rail in the United States. Relevant legislation includes the 1993 High-Speed Rail Development Act, the Swift Rail Development Act of 1994, and the Next-Generation High-Speed Rail Program. Section 1036 of the Intermodal Surface Transportation Act of 1991 (ISTEA) mandated a commercial feasibility study of high-speed ground transportation. The corridor linking the Bay Area to Los Angeles and San Diego is one of the intercity corridors designated under Section 1010 of ISTEA as having the greatest potential for high-speed rail. As such, the Corridor is eligible to receive federal funding for grade crossing safety and was examined in the commercial feasibility study.

1.3 Rationale and Historical Perspective

Embarking on a high-speed rail implementation program raises a number of fundamental questions, such as "What function should the high-speed rail system serve?", "Why build another mode of intercity transportation?", and "Why should the State government take an active role in high-speed rail implementation?" These issues are discussed below.

1.3.1 Historical Perspective

A reasonable question to ask is why a public entity might study, develop, or otherwise sponsor a mode of transportation. Historically, governments have been involved in providing transportation infrastructure, nurturing infant transportation industries, and setting out long-range transportation system plans. For example, in the 19th century, the federal government facilitated the settlement of the West by granting land to railroads. In the first decades of the 20th century, the government supported the development of the commercial aviation industry through such means as air mail contracts, investment in navigation systems, and converting military airports to civilian use. In the 1950s, development of an interstate highway system created the requisite infrastructure for goods movement and private auto travel. In a similar spirit, the state of California developed its Freeway Plan.

The need for public sector involvement has arisen from the size of the initial investment and the amount of risk to private investors. Risks are high and rates of return generally do not attract private investment in undertakings of a certain scale. Once a network of infrastructure is in place, however, building, operating, or maintaining parts of the system may become attractive to private entities. For example, now that the automobile is a ubiquitous mode of transportation, there is increasing interest in privately built and operated toll roads.

1.3.2 Rationale for Public Involvement

Economic growth and competitive advantage are the prime reasons for introduction of a new mode of intercity transportation such as high-speed rail. If the new mode offers advantages over existing modes – in terms of better reliability, travel time savings between Central Business Districts, safety, and comfort, for example – California will become a more attractive place to live and do business.

It is also argued that prices for the existing modes of intercity transportation do not fully reflect their costs to society. These impacts or externalities include phenomena such as congestion and air pollution. One way to decrease the externalities generated by transportation is to adjust prices to fully reflect the true costs. Doing so, however, would put California in an uncompetitive position against other states and countries whose transportation prices do not reflect full costs. Introduction of a competing mode such as high-speed rail that generates fewer externalities is another way to reduce negative impacts on society.

Senate Concurrent Resolution 6 states the rationale for considering high-speed rail in more specific terms. These include:

- Generation of jobs and economic growth;
- Maintenance and improvement of environmental quality;
- Saving some costs for expanding existing transportation networks (airport and highway investment);
- Improving mobility and accessibility in areas not well served by existing modes; and
- Providing an alternative to existing modes.

1.3.3 Guiding Principles or Criteria

Several guiding principles for designing and implementing the high-speed rail system were established through the enabling legislation and the work of the Commission. The high-speed rail system should:

- Improve and enhance intermodal coordination and connectivity (especially with urban transit, conventional rail, and airports);
- Focus on serving intermediate distance (100-500 miles) intercity travel;
- Develop partnerships between the public and private sectors, seeking private sector participation in financing, constructing, and operating the system as far as possible; and
- Serve California's diverse cultures and interests and afford equal opportunity to all in its development and operation.

These principles, in conjunction with the desire to use public and private resources as efficiently as possible, guided the direction of the high-speed rail technical studies and the development of the Action Plan.

2.0 Intercity Travel In California

2.0 Intercity Travel In California

In the past, California has been a pioneer in making transportation investments that both support economic activity and enhance the quality of life. Now that the State is considering whether and how to support a new mode of intercity transportation, an understanding of the current intercity travel market within the study area is critical. The Corridor of interest for this study extends from San Diego to Sacramento and includes the San Francisco Bay Area, the Central Valley, the Los Angeles metropolitan area, and portions of San Bernardino, Riverside, and Orange Counties. The metropolitan areas making up this California Corridor are listed in Table 2.1.

This chapter describes the following critical market factors that affect intercity travel demand on existing modes in the Corridor:

- Geography, population, and socioeconomic characteristics;
- Current usage of existing intercity transportation modes;
- Forecasts of future population and employment; and
- Forecasts of the intercity travel market by mode without the introduction of high-speed rail.

This chapter describes the demand for intercity travel that will exist by the year 2015 without high-speed rail. Questions regarding how much of this demand might be diverted to high-speed rail and how much additional demand might be induced are addressed in Chapter 4.0.

2.1 Geography

A key feature of California is its north-south orientation. Major population centers are arrayed in a linear fashion, although the San Francisco Bay Area is somewhat eccentric to this Corridor. This aspect of the State's geography is favorable to high-speed rail, as a population of 29.4 million, about 92 percent of California's 1994 population, may be connected in a single corridor. More challenging features of California's geography are the Tehachapi Mountains, which separate the Central Valley from the Los Angeles Basin and San Diego, and the Coastal Range, which encircles the central San Francisco Bay Area. As described in the next chapter, these mountain ranges have a profound influence on the route, cost, and choice of technology for high-speed rail.

Table 2.1 Metropolitan Areas in the California Corridor (Definition of Study Area)

Area	Geographic Definition of Catchment Area	Constituent Counties
Los Angeles	Los Angeles-Riverside-Orange County CMSA[1]	Los Angeles Orange Riverside San Bernardino Ventura
San Francisco	San Francisco-Oakland-San Jose CMSA	Alameda Contra Costa Marin Napa San Francisco Santa Clara Santa Cruz San Mateo Solano Sonoma
Sacramento	Sacramento Council of Governments (SACOG) planning area	Sacramento El Dorado (Sacramento suburbs only) Placer (Sacramento suburbs only) Yolo (eastern portion only)
San Diego	San Diego MSA[2]	San Diego
Bakersfield	Bakersfield MSA	Kern
Fresno	Fresno MSA	Fresno and Madera
Merced	Merced MSA	Merced
Modesto	Modesto MSA	Stanislaus
Monterey	Salinas MSA	Monterey
Stockton	Stockton-Lodi MSA	San Joaquin
Visalia	Visalia-Tulare-Porterville MSA	Tulare

The demographic, socioeconomic, and intercity travel statistics described in this chapter correspond to these geographic definitions, which were developed for the ridership forecasting process.

Notes: (1)Consolidated Metropolitan Statistical Area
(2)Metropolitan Statistical Area

Source: Charles River Associates, 1996.

2.2 Socioeconomic Characteristics and Trends

2.2.1 Population

A fixed-guideway mode such as high-speed rail most efficiently serves only the more densely populated corridors. Thus, the current and projected population within the Corridor is a significant determinant of the demand for intercity travel and the feasibility of high-speed rail. Some 29 million people resided within the Corridor (from Sacramento to San Diego) in 1994, representing 92 percent of the State's population (see Table 2.2). The major metropolitan areas centered around Los Angeles and San Francisco account for about 76 percent of the Corridor's total population. The seven Central Valley metropolitan areas (Sacramento, Bakersfield, Fresno, Modesto, Merced, Stockton, and Visalia) have a combined population of 4.1 million, or about 14 percent of the total Corridor population. These population centers are arrayed along a corridor of over 600 miles in length from San Diego to Sacramento.

By 2015, the Corridor population is expected to reach 41.5 million. The major metropolitan areas will remain the largest population centers (over 22 million in the Los Angeles area and over 8 million in San Francisco Bay Area). The seven Central Valley metropolitan areas are expected to grow at a somewhat faster rate, reaching 7 million by 2015.

2.2.2 Income

Per capita income is another significant determinant of the demand for intercity travel. The San Francisco and Los Angeles metropolitan areas show the highest per capita income levels in the Corridor, closely followed by the Monterey, San Diego, and Sacramento metropolitan areas (see Table 2.3). This pattern of income distribution is expected to continue over the next 45 years with the established major metropolitan areas having slightly higher rates of per capita income growth.

2.3 The Existing Intercity Travel Network

2.3.1 Air

Air travel accounts for 12 percent of the Corridor's total intercity transportation market and a much higher percentage of longer distance travel (over 200 miles). For example, air served 61 percent of the total trips taken in 1994 for travel between Los Angeles and the Bay Area. Indeed, the Los Angeles to San Francisco market is the busiest air market in the United States, and one of the most heavily trafficked in the world. Los Angeles

Table 2.2 Historical and Projected Population for California Corridor Metropolitan Areas

Year	Los Angeles	San Francisco	San Diego	Sacramento	Bakersfield	Fresno	Modesto	Merced	Monterey	Stockton	Visalia	Total
1980	11,549,300	5,386,500	1,873,300	787,900	406,100	581,300	267,700	135,500	292,100	350,200	247,400	21,877,300
1981	11,784,400	5,464,500	1,921,800	806,700	419,000	596,100	275,500	139,800	299,900	362,000	254,000	22,323,700
1982	12,058,900	5,540,500	1,965,100	832,200	433,600	610,500	281,100	143,000	306,600	374,100	260,200	22,805,800
1983	12,328,800	5,634,700	2,003,500	852,900	446,900	626,900	289,100	148,000	314,400	386,700	267,600	23,299,500
1984	12,564,400	5,706,300	2,055,700	869,800	459,200	644,100	294,500	152,100	321,700	399,800	273,800	23,741,400
1985	12,856,100	5,800,700	2,109,300	890,700	473,800	657,600	302,000	157,000	327,400	417,200	280,600	24,272,400
1986	13,212,100	5,884,200	2,182,900	918,200	485,900	669,300	312,600	159,500	333,700	433,700	286,600	24,878,700
1987	13,562,200	5,960,400	2,260,700	951,400	497,900	687,700	325,200	162,900	338,400	448,800	292,700	25,488,300
1988	13,888,400	6,057,800	2,341,000	981,700	511,200	708,800	338,300	167,800	343,000	461,400	299,200	26,098,600
1989	14,252,600	6,173,700	2,432,800	1,011,800	525,100	732,000	354,200	172,000	346,600	471,500	304,000	26,776,300
1990	14,630,400	6,281,800	2,520,100	1,051,800	549,600	763,300	376,100	180,500	358,500	484,400	314,700	27,511,200
1991	14,930,000	6,384,100	2,579,600	1,067,400	574,800	795,200	388,700	187,200	365,200	497,500	327,400	28,097,100
1992	15,221,800	6,501,500	2,636,600	1,108,500	595,100	823,900	400,300	191,900	373,000	509,100	337,600	28,699,300
1993	15,401,000	6,593,700	2,665,900	1,123,800	609,800	846,500	409,500	196,800	376,600	518,500	343,500	29,085,600
1994	15,554,100	6,668,900	2,705,800	1,137,400	622,900	865,300	417,200	201,200	369,000	526,600	352,100	29,420,500
1995	16,114,250	6,756,750	2,769,450	1,190,250	675,900	921,800	446,850	209,800	386,400	552,050	365,950	30,389,450
2000	17,599,200	7,231,200	3,018,400	1,329,100	802,000	1,079,900	517,600	239,000	414,000	620,300	417,300	33,268,000
2005	19,039,500	7,533,500	3,247,250	1,454,200	919,850	1,244,550	593,800	276,300	449,650	699,350	469,250	35,927,200
2010	20,479,800	7,835,800	3,476,100	1,579,300	1,037,700	1,409,200	670,000	313,600	485,300	778,400	521,200	38,586,400
2015	22,123,300	8,095,350	3,728,300	1,709,400	1,173,900	1,606,500	755,100	357,750	529,700	867,450	582,800	41,529,550
2020	23,766,800	8,354,900	3,980,500	1,839,500	1,310,100	1,803,800	840,200	401,900	574,100	956,500	644,400	44,472,700
2025	25,595,250	8,588,600	4,242,250	1,969,400	1,463,100	2,041,550	932,800	454,100	622,500	1,052,600	716,500	47,678,650
2030	27,423,700	8,822,300	4,504,000	2,099,300	1,616,100	2,279,300	1,025,400	506,300	670,900	1,148,700	788,600	50,884,600
2035	29,301,650	8,986,600	4,757,200	2,225,650	1,785,450	2,547,450	1,125,150	566,600	722,100	1,252,600	870,350	54,140,800
2040	31,179,600	9,150,900	5,010,400	2,352,000	1,954,800	2,815,600	1,224,900	626,900	773,300	1,356,500	952,100	57,397,000
Average Annual Growth												
1980-1994	2.1%	1.5%	2.7%	2.7%	3.1%	2.9%	3.2%	2.9%	1.7%	3.0%	2.6%	2.1%
1995-2040	1.5%	0.7%	1.3%	1.5%	2.4%	2.5%	2.3%	2.5%	1.6%	2.0%	2.1%	2.0%

Source: California Department of Finance with calculations by Charles River Associates.

Table 2.3 Historical and Projected Real Income Per Capita for California Corridor Metropolitan Areas ($1993)

Year	Los Angeles	San Francisco	San Diego	Sacramento	Bakersfield	Fresno	Modesto	Merced	Monterey	Stockton	Visalia
1980	$20,529	$22,796	$18,617	$18,487	$18,636	$18,490	$16,865	$16,395	$19,053	$18,196	$16,184
1981	$20,482	$22,939	$18,642	$18,281	$17,774	$17,467	$16,439	$14,890	$19,077	$17,524	$15,275
1982	$20,365	$23,251	$18,637	$17,517	$17,361	$16,361	$15,962	$14,085	$18,849	$16,849	$14,652
1983	$20,666	$24,131	$19,140	$17,803	$16,655	$15,866	$15,822	$13,606	$20,008	$19,381	$13,883
1984	$21,604	$25,292	$19,970	$18,621	$17,230	$16,535	$16,511	$14,848	$20,020	$17,240	$14,471
1985	$22,180	$25,824	$20,764	$19,526	$17,340	$16,871	$17,061	$15,105	$20,297	$17,437	$14,455
1986	$22,771	$26,480	$21,535	$20,361	$17,726	$17,389	$17,484	$15,759	$21,113	$17,857	$14,913
1987	$23,014	$26,575	$21,613	$20,510	$17,181	$17,772	$17,619	$15,974	$21,204	$17,996	$15,408
1988	$23,058	$27,040	$21,729	$20,459	$17,302	$17,447	$17,463	$15,682	$21,171	$17,965	$15,444
1989	$22,946	$27,178	$22,117	$20,802	$17,247	$17,658	$17,787	$16,033	$21,175	$18,120	$15,515
1990	$22,845	$27,368	$21,814	$21,084	$17,338	$17,878	$17,833	$15,772	$21,575	$17,892	$15,910
1991	$21,945	$26,586	$21,086	$20,524	$16,605	$17,092	$17,165	$14,914	$21,056	$17,372	$14,942
1992	$21,800	$26,798	$20,994	$20,775	$16,310	$17,157	$17,239	$15,158	$20,930	$17,449	$15,464
1993	$21,388	$27,293	$20,950	$20,751	$16,312	$17,215	$17,083	$15,082	$21,371	$17,808	$15,319
1994	$21,579	$27,687	$21,202	$20,999	$16,331	$17,286	$17,216	$15,135	$21,625	$17,921	$15,393
1995	$22,981	$28,130	$22,201	$21,702	$17,372	$17,946	$18,212	$16,060	$22,010	$18,400	$16,100
2000	$24,631	$29,961	$23,845	$23,115	$18,748	$19,275	$19,534	$17,249	$23,550	$19,669	$17,170
2005	$26,280	$31,793	$25,490	$24,528	$20,124	$20,604	$20,856	$18,439	$25,091	$20,939	$18,241
2010	$27,396	$33,523	$26,825	$25,700	$20,382	$20,993	$21,620	$18,795	$26,258	$21,453	$18,622
2015	$28,513	$35,252	$28,159	$26,872	$20,640	$21,382	$22,383	$19,151	$27,425	$21,967	$19,003
2020	$29,629	$36,982	$29,494	$28,045	$20,899	$21,771	$23,147	$19,508	$28,593	$22,482	$19,385
2025	$30,746	$38,711	$30,828	$29,217	$21,157	$22,160	$23,910	$19,864	$29,760	$22,996	$19,766
2030	$31,862	$40,441	$32,163	$30,389	$21,415	$22,549	$24,674	$20,220	$30,927	$23,510	$20,147
2035	$32,978	$42,171	$33,498	$31,561	$21,673	$22,938	$25,438	$20,576	$32,094	$24,024	$20,528
2040	$34,095	$43,900	$34,832	$32,733	$21,931	$23,327	$26,201	$20,932	$33,261	$24,538	$20,909
Average Annual Growth											
1980-1994	0.4%	1.4%	0.9%	0.9%	-0.9%	-0.5%	0.1%	-0.6%	0.9%	-0.1%	-0.4%
1995-2040	0.9%	1.0%	1.0%	0.9%	0.5%	0.6%	0.8%	0.6%	0.9%	0.6%	0.6%

Source: Center for Continuing Study of the California Economy with calculations by Charles River Associates.

International (LAX) and San Francisco International (SFO) are among the five busiest airports in the United States, in terms of enplanements.[1] Eight California airports are among the 50 busiest in the United States.[2] Five airports serve the major metropolitan areas of Los Angeles (LAX, Burbank, Ontario, John Wayne, and Long Beach) and three airports serve the San Francisco Bay Area (SFO, San Jose, and Oakland). Figure 2.1 shows the airports serving the Corridor.

In 1994, California Corridor airports served 16.8 million one-way passenger trips. About 13.9 million of these trips were local with both trip origins and destinations within the Corridor. The remaining 2.9 million trips were for connecting passengers traveling through either San Francisco International (SFO) or Los Angeles International (LAX) airports with a final destination or trip origin outside of California. A passenger flying from Fresno to San Francisco and then transferring to a flight to Hawaii would be a connecting passenger, for example.

Airlines compete intensely for passengers traveling between the Corridor's major metropolitan areas. Their service is characterized by high flight frequencies and relatively low fares. For example, there were an average of 187 daily flights in each direction between the Los Angeles and Bay Area regions in 1994. The average one-way fare was $74 for business passengers, and $41 for non-business passengers. These fares are typical of the low fares historically found in the San Francisco – Los Angeles market. Airfares have not fluctuated much in the last 15 years, and the prospects of continued competition in this market remain strong.

In contrast, there are far fewer flights to, from, and between Central Valley cities and fares are much higher. The average one-way fare paid between Fresno and SFO, for example, was $133 for business passengers and $74 for non-business passengers in 1994. This market was served by an average of 18 daily flights. Scheduled, in-flight travel time is one hour and 18 minutes between LAX and SFO and 53 minutes between SFO and Fresno.

2.3.2 Private Vehicles

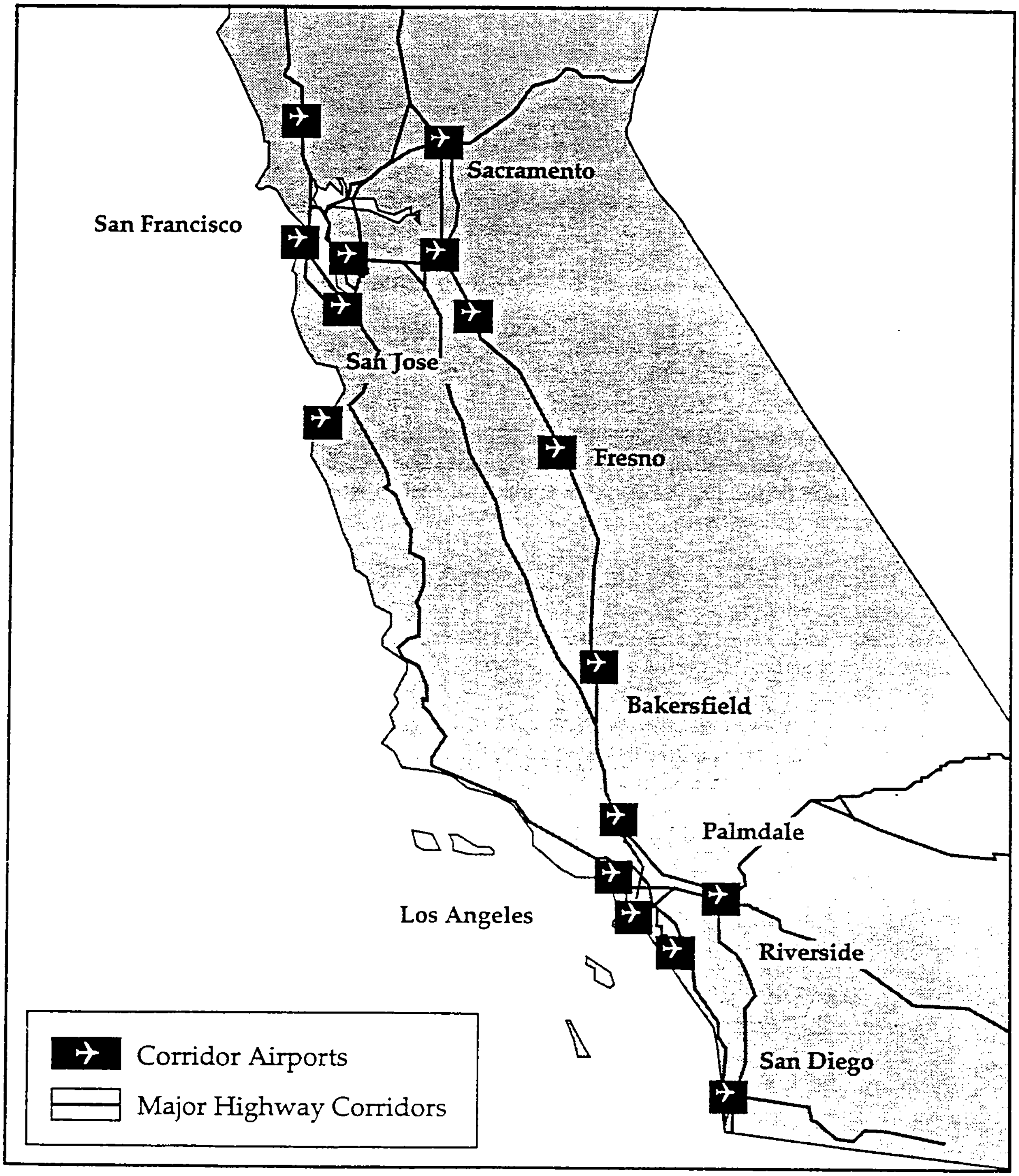
California has constructed an extensive network of limited-access highways connecting metropolitan areas (see Figure 2.1). Major north-south routes include U.S. 101, Interstate 5 (I-5), and State Route 99 (SR-99). Unlike air travel, private vehicle travel is not constrained by schedules or service frequencies. The trip between downtown Los Angeles and downtown San Francisco takes about six-and-a-half hours via I-5. Highway travel between downtown San Francisco and downtown Fresno averages around two and a half hours.[3] Travelers perceive their out-of-pocket travel cost to be $0.10 per person-mile for

[1]Volpe National Transportation Systems Center (1995).

[2]Ibid.

[3]Private vehicle travel times were calculated from Metropolitan Planning Organization and Caltrans' highway network models as part of the ridership forecasting process (see Chapter 4.0).

Figure 2.1 Corridor Airports and Highway System



business travel and $0.05 per person-mile for non-business travel.[4] The intercity highway network in the Corridor served over 126 million person trips in 1994, an 87 percent share of intercity travel in the Corridor. About 28 percent of the private vehicle trips are for business and 72 percent for leisure purposes.

2.3.3 Intercity Rail

Although rail was historically the dominant mode of intercity passenger transportation, this mode has long been eclipsed by air and auto travel. Conventional passenger rail service in California, however, has recently received support through the passage of Propositions 108 and 116 and State support for intercity passenger rail services provided through Amtrak. In addition, the State has purchased 66 specially designed "California Cars" and nine locomotives for use on intercity rail routes within California.

Amtrak operates six "basic system" routes that serve parts of the Corridor and are federally supported. In addition, the State supports three intercity rail routes through the provisions of Section 403(b) of the Rail Passenger Service Act. These include the *Capitols* between San Jose and Sacramento, the *San Joaquins* connecting the Bay Area and Sacramento to Bakersfield, and extra trains on the *San Diegan* route between Los Angeles and San Diego (see Figure 2.2). A system of feeder bus lines extends the service area of the intercity rail system.

The frequency of rail service is low compared to that of airlines. For example, there were an average of four daily feeder bus or rail departures in each direction between San Francisco and Los Angeles (and serving Fresno) in 1994. Fares averaged $51 between San Francisco and Los Angeles and $30 between Fresno and San Francisco. Despite the relatively low frequency of service provided between metropolitan areas, California's intercity rail system served an estimated 1.8 million passengers in 1994, about 1 percent of the market.[5] Over one million of these passengers rode on the *San Diegans*, Amtrak's second most successful service after the Northeast Corridor.

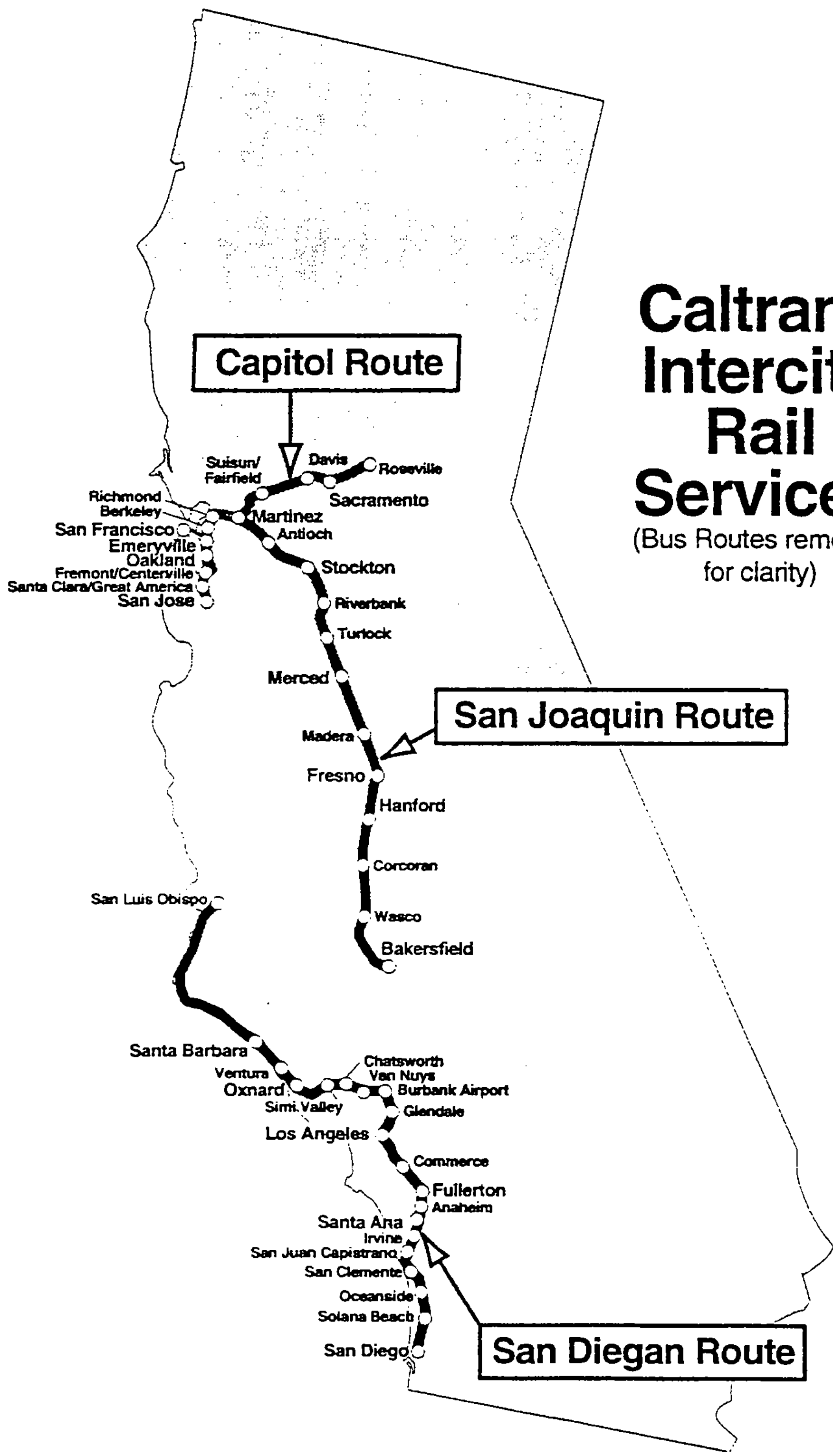
2.3.4 Commuter and Urban Rail

While the focus of this study is on *intercity* travel, commuter and urban rail systems serve as important feeders to the intercity modes and enhance the accessibility of intercity passenger terminals. Existing commuter rail systems include the CalTrain service in the Bay Area and the Metrolink system in the Los Angeles region. Urban rail systems connecting to the intercity transportation network include BART in the Bay Area, the San Diego Trolley, the Los Angeles Area Urban Rail, the Santa Clara County Light Rail, the San

[4] These figures were developed from survey data and ref... travelers' *perceived* out-of-pocket cost for expenses such as gas and bridge tolls.

[5] This figure includes trips that may consist in part of a bus connection.

Figure 2.2 Caltrans Intercity Rail Services



Francisco Municipal Railway, and the Sacramento Light Rail. Several of these urban or commuter services run over rights-of-way that are being considered for high-speed rail service, raising the possibility of sh d use of rail infrastructure as well as right-of-way.[6]

2.4 Market Shares

2.4.1 The Current Picture

In 1994, private vehicles accounted for 87 percent of all intercity trips taken in the San Diego-Sacramento Corridor. Air travel accounted for 12 percent and rail accounted for the remaining 1 percent (see Figure 2.3 and Table 2.4).

About 83 percent of the air trips (or 10 percent of the total market) are "local" to the California Corridor, while 17 percent (or 2 percent of the total market) involve connections to locations outside California. About 53 percent of the trips made by air are for business purposes. While air accounts for only 12 percent of the total market, this mode captures almost 20 percent of the business travel.

Of the trips made by private vehicle, 19 percent (or 16 percent of the total market) are classified as "en-route captive"; that is, the travelers need their vehicles to make stops along the way. Another 35 percent (or 30 percent of the total market) of the auto trips are "destination captive" trips that require a private vehicle at their destination. The remaining 47 percent of trips made by auto, as well as the destination captive trips (for which autos can be rented at the destinations), are considered candidates for diversion to other modes of transportation. About 72 percent of the trips made by auto are for non-business purposes.

2.4.2 The Future Market

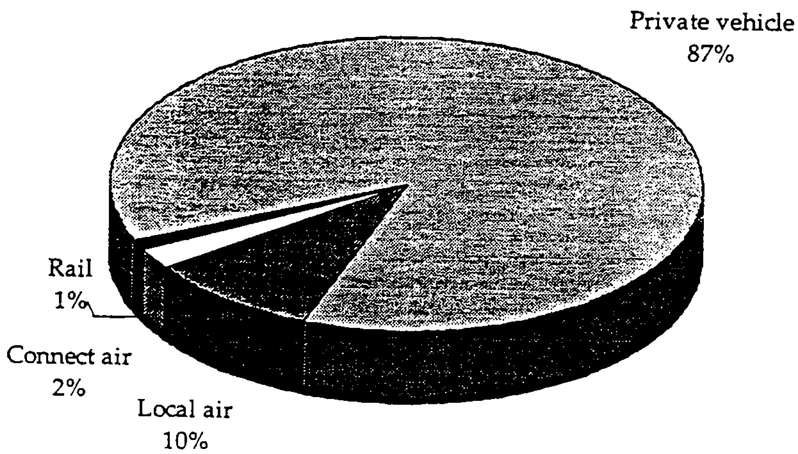
The total market for intercity passenger transportation in the Corridor is expected to grow by about 32 percent by the year 2015, an additional 47 million trips.[7] Because of the sheer volume of private vehicle travel, especially for shorter distance intercity travel, most of the additional trips will take place on highways, although air travel is expected to grow at a faster rate. The expected average annual growth rates for the various modes range from 1.2 percent for auto trips to 2.5 percent for connecting air travel (see Table 2.4). Assuming service levels remain constant, the distribution of intercity travel by mode is expected to remain largely unchanged in 2015, as illustrated by the second pie chart in Figure 2.3.

[6]There are significant service coordination, equipment compatibility, safety, and cost sharing issues involved, however.

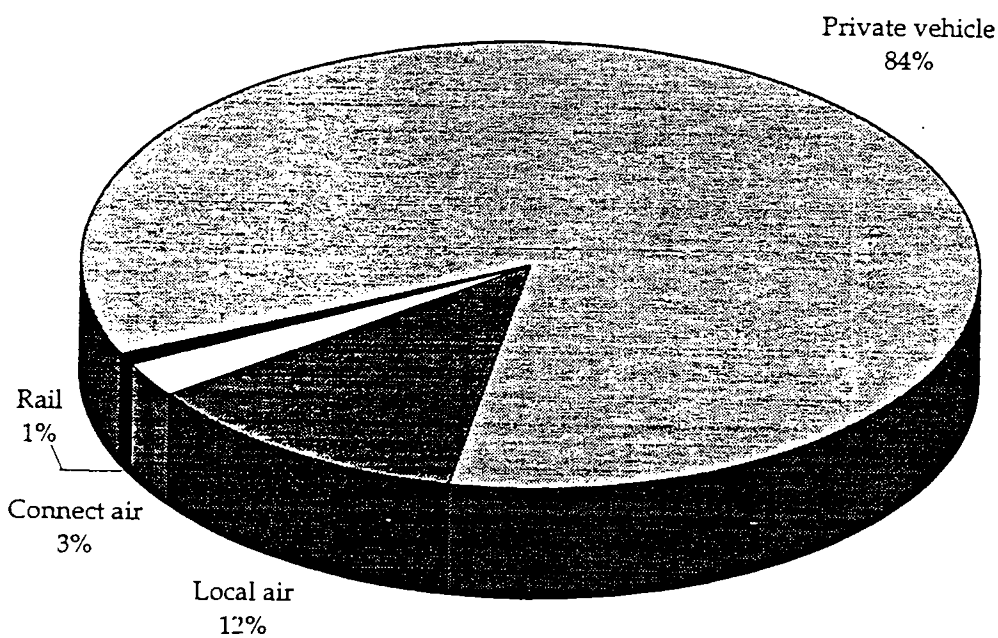
[7]Removing the "en-route captive" auto trips, a market of 162 million annual passenger trips exists as potential candidates for diversion to high-speed rail. High-speed rail also has the potential to induce additional intercity travel; trips that would not otherwise have been made without the presence of high-speed rail. Chapter 4.0, *Ridership and Revenue*, presents forecasts of the potential market share for high-speed rail in the 2015 intercity travel market.

Figure 2.3 Market Share (without High-Speed Rail)

Base Year (1994)



Forecast Year (2015)



Note: Total market is defined as the corridor between San Diego and Sacramento. It does not include intercity bus trips.

Source: Charles River Associates, 1996.

Table 2.4 Growth in Intercity Travel Without High-Speed Rail for the San Diego-Sacramento Corridor (1994–2015)

Mode	Annual Person Trips 1994	Annual Person Trips 2015	Average Annual Growth Rate (1994-2015)
Local air	13,899,307	22,823,126	2.39%
Connect air	2,923,113	4,909,608	2.50%
Rail [1]	1,793,044	1,793,044	0.00%
Private vehicle (all)	126,713,392	162,906,452	1.20%

Note: [1] For travel demand forecasting purposes, the ridership for the existing intercity passenger rail services was conservatively assumed to remain constant through 2015.

Source: Charles River Associates, 1996.

Accommodating the future demand for intercity travel in California will be a challenge. Three of the major airports in the Corridor – Los Angeles International (LAX), San Francisco International (SFO), and San Diego – face capacity constraints leading to significant delay. At the same time, proposals to significantly increase airside capacity face considerable environmental challenges. Airlines and airports are likely to adopt some mixture of demand management and market responses to the prospect of increased delays. Such responses, including increased landing fees, peak period pricing, and flights to less congested airports, may decrease the comfort and convenience of air travel in the future.

Highways similarly face increasing congestion with constraints on significant capacity enhancements. While most congestion occurs in metropolitan areas as a result of intra-urban travel, this congestion impacts intercity trips at trip origin and destination. This urban highway congestion, combined with responses to airside delays, could make existing urban centers increasingly inaccessible in the future. These factors highlight the need to consider alternative means of enhancing California's intercity transportation network.

3.0 High Speed Rail Alternatives

3.0 High Speed Rail Alternatives

3.1 Introduction

This chapter summarizes the findings of the Corridor Evaluation and Environmental Constraints Analysis. The objectives of this study were to define the most promising alternatives for the high-speed rail alignment, develop capital and operating cost estimates, assess the technology options, and perform a planning level analysis of environmental impacts. Travel time simulations developed during this process served as inputs to the ridership and revenue forecasts (Chapter 4.0) while operating and capital cost estimates were inputs to the financial plan (Chapter 6.0) and the economic impacts analysis (Chapter 7.0).

Assessing the feasibility and advisability of high-speed rail in California required evaluation of a large number of technology and alignment alternatives. This chapter describes the technology and alignments studied; the process used to narrow the range of alternatives carried forward for more detailed analysis; and the costs, travel times, station locations, and environmental impacts associated with the various alternatives. This chapter is organized into the following sections:

- Technology Evaluation;
- The Evaluation Process;
- Alignment Options;
- Capital Costs;
- Station Locations;
- Operating Scenario and Travel Times;
- Operating Costs; and
- Environmental Impacts.

3.2 Technology Evaluation

Existing and emerging candidate high-speed rail technologies were reviewed and compared, not to select a single technology or particular manufacturer, but to establish generic design criteria and performance characteristics. The candidate high-speed rail technologies comprise three general groups:

- High Speed – maximum operating speeds up to 150 mph (250 kph);
- Very High Speed – maximum operating speeds up to 217 mph (350 kph); and
- Magnetic Levitation – maximum operating speeds up to 310 mph (500 kph).

Table 3.1 provides detailed operational characteristics for the three technology grou , that are described below.

3.2.1 High Speed Group

The High Speed (HS) group comprises upgraded traditional passenger rail technology. High speed systems use either diesel, diesel-electric, gas turbine, or electric power, and typically operate on existing rail rights-of-way that have been upgraded through sub-grade, track, signal, grade-crossing protection, grade separation and/or construction of passing sidings. "Tilt-train" rolling stock is often used in this technology category to permit higher operating speeds through curves in existing alignments. Because this technology group maximizes the use of existing rights-of-way and can share tracks with other rail services, HS technology can usually be implemented with less capital investment and fewer environmental disruptions than higher speed technologies. However, conflicts with existing lower speed freight service can arise when sharing rights-of-way.

3.2.2 Very High Speed Group

The Very High Speed (VHS) group provides steel-wheel-on-rail service at speeds significantly greater than those afforded by HS systems. These speeds require a dedicated, fully grade-separated right-of-way with more stringent restrictions on horizontal and vertical curvature than those needed for lower speed technologies. All VHS systems now in operation use electric propulsion with overhead catenary. Among those now in operation are the systems in:

- France – *Train a Grande Vitesse (TGV)* operating at 186 mph;
- Germany – *Intercity Express (ICE)* operating at 155 mph;[1]
- Japan – *Shinkansen* operating at 170 mph; and
- Spain – *Alta Velocidad Espanol (AVE)* operating at 167 mph.

[1]The ICE operate at 172 mph when needed to keep on schedule.

Table 3.1 High-Speed Rail Technology Groups – Operational Characteristics Comparison

	HS	VHS	Maglev
GENERAL			
• Technology	Steel wheel/steel rail	Steel wheel/steel rail	Magnetic levitation
• Motive Power/Propulsion	Electric traction locomotives with catenary	Electric traction locomotives with catenary	Linear induction motors
OPERATIONS			
• Top Speed	125 - 150 mph	180 - 220 mph	200 - 310 mph
• Average Speed	75 - 95 mph	125 -155 mph	155 - 185 mph
• Acceleration (mph/s)			
– 0 - 60 mph	0.9	1.1	3.1
– 60 - 120 mph	0.5	0.6	1.8
– > 120 mph	0.2	0.2	1.1
• Deceleration (mph/s)	1.8	1.6	1.8
CIVIL			
• Superelevation	6 degrees	7 degrees	16 degrees
• Gradient			
– Maximum	3.0%	3.5%	6.0%
– Absolute Maximum(1)	5.0%	5.0%	10.0%
• Horizontal Curvature(2)			
• Desired Min. Radius at Maximum Speed	6,200 ft @ 125 mph	17,500 ft @ 220 mph	23,300 ft @ 310 mph
• Absolute Min. Radius at Maximum Speed	6,200 ft. @ 125 mph	16,700 ft. @ 220 mph	18,000 ft. @ 310 mph
• For Tilt Technology	4,100 ft @ 125 mph		
• Vertical (Sag) Curvature(2)			
• Minimum Radius at Maximum Speed	34,000 ft @ 125 mph	105,000 ft @ 220 mph	214,200 ft @ 310 mph
• Vertical (Crest) Curvature			
• Minimum Radius at Maximum Speed	52,000 ft @ 125 mph	168,000 ft @ 220 mph	321,500 ft @ 310 mph
• Right-of-way Requirements	50 ft. min.	50 ft. min.	Slightly Less

Notes: (1) Gradients shown represent the capability of the technology group. No high speed railroad currently operates at gradients over 3.5 percent.

(2) Horizontal and vertical curvatures are limited by passenger comfort and not the physical limitations of the technology.

Source: Parsons Brinckerhoff, 1996.

3.2.3 Magnetic Levitation (Maglev) Group

This technology group departs from the wheel-rail system in using either attractive or repulsive magnetic forces to lift and propel the vehicles along a guideway. Magnetic levitation allows the vehicles to hover a small distance above a guideway; thereby eliminating friction and rolling resistance. Although right-of-way may be shared, the unique dedicated guideway precludes shared use of track with steel-wheel-on-rail systems.

In 1990, the National Maglev Initiative (NMI) was formed by the United States Department of Transportation, the Army Corps of Engineers, and the Department of Energy to research and assess Maglev's potential and to develop several U.S.-based concepts for Maglev systems. However, continued federal funding for Maglev has not materialized. Active prototype testing continues in Japan and Germany with systems currently under development designed for speeds of 310 mph and beyond. Although no Maglev technologies are yet in revenue service, the success of the German Transrapid System's 20-mile guideway has led to its certification for application in Germany

3.2.4 Comparison of High Speed Technologies

General Assessment and Reliability

Both the HS and VHS technology groups are viable candidates that have been proven in revenue service over an extended period. In contrast, Maglev has not yet been tested in revenue service. Existing HS and VHS systems have an excellent reliability record (the French TGV, for example, has achieved a 97 percent on-time record). There is no reason to suspect that HS or VHS cannot be equally reliable in California. Although its developers predict an even higher reliability for Maglev technology due to fewer mechanical components, as mentioned, there is no revenue service history to substantiate this claim.

Right-of-Way and Alignment Requirements

HS and VHS equipment can travel on existing, electrified rail networks at greatly reduced speeds. Thus, the HS or VHS technology would allow for an incremental upgrade process, whereas Maglev would not . However, all of the technology options will require a fully grade-separated and electrified alignment with a dual track or guideway system. High-speed operation requires very straight alignments (for example, the minimum curve radius required to allow full speed operation for VHS is over three miles). Since most urban railroad and highway rights-of-way do not meet the criteria for high-speed operations, new rights-of-way must be acquired or speeds reduced.

With regard to grade climbing capability, Maglev has a significant advantage since its maximum design grade is twice that of HS and VHS (10 percent vs. 5 percent). This ability could reduce tunneling requirements in certain areas.

Shared Operations

HS and VHS trains can share tracks with other compatible steel-wheel-on-rail services such as commuter trains or conventional intercity rail (existing freight services are unlikely to ever become compatible). All the high-speed rail technology groups can share right-of-way with other services, where there is adequate width. The pressure to share tracks or right-of-way is especially acute in the major metropolitan areas where acquisition of right-of-way is difficult and costly.

There are severe constraints on shared operations, however. In addition to the scheduling conflicts inherent in shared track, there are issues of equipment compatibility. Existing rail services in the United States (freight in particular) use much heavier equipment than that proposed for HS, VHS, or Maglev passenger service. The wear and tear caused by existing freight renders tracks unsuitable for high speed operations. Moreover, differences in equipment strengths will require a crash barrier to separate HS, VHS, or Maglev service from incompatible equipment in shared rights-of-way.[2] Finally, existing freight services use diesel locomotives while high-speed rail requires electric traction.

Acceleration and Deceleration

Due to differences in propulsion and power distribution methods, Maglev can accelerate much faster than HS or VHS technology. Deceleration is similar for all of the groups since it is limited by passenger comfort.

Speed and Energy Consumption

Computer simulation of the Los Angeles to San Francisco trip indicates that VHS technology is 15-25 percent faster than HS technology, depending on the number of stops, while Maglev is 25-45 percent faster. HS technology consumes far less energy than either VHS or Maglev, but only because of the lower speeds involved. At 100 mph (160 km/h), VHS and Maglev consume about the same energy per unit of distance. As speeds increase, both technology groups consume more energy, but Maglev always consumes less than VHS at equivalent speeds.

Safety

No train-related passenger fatalities have occurred during 30 years of high-speed service on the Japanese Shinkansen and 15 years of service on the French TGV. VHS technology has enjoyed this remarkable safety record primarily because VHS systems do not have grade crossings or share tracks with slower services. Under similar constraints, the HS and Maglev technology groups should be equally safe. To achieve this level of safety, right-of-way fencing and intrusion barrier installation for both protection and containment must be integrated into any high-speed rail system design.

[2]The recently-approved merger of the Southern Pacific and Union Pacific railroads may obviate the need for such crash barriers in some cases if freight services is discontinued on certain corridors.

With regard to seismic safety and electromagnetic field concerns, there is little difference among the technology groups. The seismic design objective of the high-speed rail system, regardless of technology, is to pr‑‑ect passengers by preventing catastrophic failure in an earthquake. In addition, the sy‑ ‑n should be serviceable after a short closure for repair or shoring of minor damage.

Passenger Comfort

The ride quality of HS and VHS services is superior to any other form of transportation. Passengers are not required to wear seat belts and are free to leave their seats at all times. Passenger comfort is governed by design criteria that limit the amount of force passengers experience in horizontal and vertical curves, and in acceleration or deceleration. Maglev developers have advocated for more relaxed design cr‑ ‑eria in California, to permit faster speeds and accelerations and to save on infrastructure costs. If such relief were granted, the Maglev ride would be closer to that experienced in air travel.

Noise and Visual Impact

Maglev is quieter than either HS or VHS operating at the ‑ame speed. At top speeds, all technology groups generate about the same noise level. Mitigation such as sound walls or speed reduction will be required in sensitive areas for all technology groups. Regarding visual impacts, HS and VHS require overhead catenary structures, whereas Maglev does not. Modern catenary designs, however, are far less obtrusive than their predecessors. On the other hand, Maglev requires at-grade guideway structures that some may consider more obtrusive than conventional HS and VHS track systems.

3.2.5 Potential for High-Speed Freight

The type of freight that high-speed rail would carry, and the equipment involved is quite different from the typical U.S. freight operation. The freight carried by U.S. railroads is typically low value or non time-sensitive and does not justify high-speed operating costs. Moreover, the equipment used by U.S. freight railroads is far too heavy to be compatible with high-speed rail alignment and operating requirements. Thus, this assessment focused on the high-value and time-sensitive freight markets that can support the greater high-speed operating costs, and are compatible with specialized, light-weight, high-speed rail freight equipment.

Freight compatible with high-speed rail weight restrictions could be carried in special flatcars or container equipment as is done on German high-speed rail lines. Such trains would run at about 100 mph, (high-speed freight trains would need to make the trip between Los Angeles and the San Francisco Bay Area in under six hours to be competitive), but would not gain any competitive advantage from faster running. The high-speed freight trains would operate during late night or early morning hours to avoid disrupting the passenger schedule. It is unlikely that this type of freight service could be operated profitably over grades greater than 3.5 percent for rail technology because of higher operating costs.

Another type of high-value freight would be small package or express mail service operated during the day or evening hours; either using space on passenger trains or on a "freighter" version of the passenger vehicle. This type of service is provided in France, where two TGV postal trains carry mail between Paris and Lyon. High-speed package or express mail service may be operated profitably over the same grades as passenger service.

The potential for a viable, commercial service does exist, and is compatible with the candidate technologies. A conservative estimate of the net freight revenue that could be earned by the high-speed rail system is $20 million per year. Implementation of a successful service will require careful planning, however. High-speed rail will need to provide more than a line-haul freight alternative; pick-up and distribution networks must be considered as well.

3.3 The Evaluation Process

3.3.1 Overview of Alignment Options

California's high-speed rail legislation identified the Los Angeles-San Francisco Bay Area Corridor as the primary focus of the study. Secondary consideration was to be given to extensions of service to San Diego and Sacramento. There are three general routes between Los Angeles and San Francisco as shown in Figure 3.1:

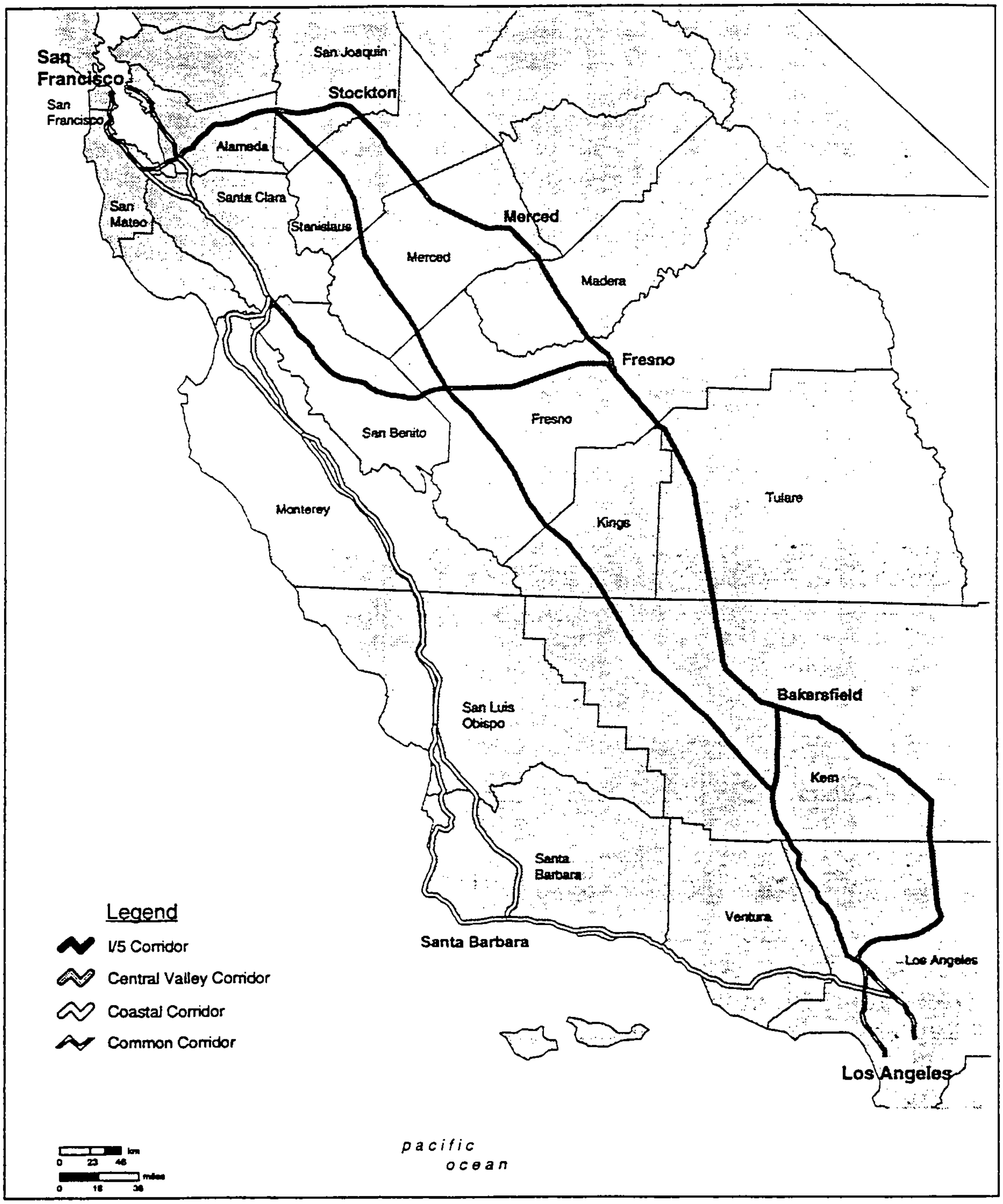
- The Coastal Corridor;
- The Interstate 5 Corridor; and
- The Central Valley (State Route 99) Corridor.

These corridors generally follow the three major intercity highways between northern and southern California: Highway 101, Interstate 5 (I-5), and State Route 99 (SR-99).

An additional set of alignment options involves crossing the mountain ranges separating the San Francisco Bay Area and the Los Angeles Basin from the Central Valley. In Southern California, there are three basic options for crossing the Tehachapi Mountains between Los Angeles and Bakersfield. The most direct route follows the I-5 alignment and crosses the mountains via the Grapevine. Two alternative alignments cross the Tehachapis at either the Mojave or Aqueduct passes serving the Antelope Valley and Palmdale .

In Northern California, there are three potential alignments to connect the San Francisco Bay Area with the I-5 and SR-99 Corridors. The Panoche Pass is the southernmost, running east from Fresno. The Pacheco Pass is further north, running along the approximate alignment of State Route 152 from Chowchilla to Gilroy. The northernmost connection is the Altamont Pass running along the Interstate 580 Corridor between Stockton and the Bay Area.

Figure 3.1 Major Corridor Alternatives



Other important alignment alternatives concern routing within the major metropolitan areas of Los Angeles and the San Francisco Bay Area, and options for extending the system to San Diego and Sacramento. In Southern California, alignment options connecting to either or both Union Station and Los Angeles International Airport were developed, San Diego could be served via the existing LOSSAN Corridor or via a new alignment following Interstate 15. In Northern California, a major alignment decision is whether to serve the Bay Area with a high-speed rail alignment along the Peninsula (serving the airport and San Francisco), or with an East Bay route (serving Oakland). Another issue concerns service to San Jose, which could be provided with a direct line if the Altamont Pass option were selected. Service to Sacramento could follow either the existing Capitol Corridor or a Stockton route.

Finally, in the Antelope Valley and rural Central Valley there are often several alignment sub-options. Typically, the choice is between directly serving existing city centers or skirting urbanized areas, resulting in high and low cost estimates. These sub-options for routing affect station location and system accessibility as well as cost.

3.3.2 Study Phases and Findings

The vast number of potential configurations of the available alignment options (including technology, major corridor, mountain crossings, service in urban areas, and system extensions) made necessary a screening and evaluation process prior to proceeding with more detailed analysis. The potential high-speed rail alignments were evaluated in three phases:

- Phase 1 – Initial screening of major corridor alternatives;
- Phase 2 – More detailed evaluation of Los Angeles to San Francisco alignments; and
- Phase 3 – Evaluation of extensions to Sacramento and San Diego.

This section summarizes the analyses and findings of study Phases 1, 2, and 3. The more detailed findings on the alignment options that survived the screening process during Phases 1 and 2, along with details on methodology, are presented in the remaining sections of this chapter.

Throughout each phase, data were developed to evaluate the alternatives in terms of three principal objectives:

- Maximize ridership potential;
- Minimize costs; and
- Avoid potential environmental constraints.

Phase 1 Summary

Phase 1 comprised an initial, broad-scale review of major corridor alternatives between Los Angeles and the San Francisco Bay Area (the Coastal, I-5 and SR-99 Corridors) to identify those with the greatest potential for high-speed rail service.

The initial review indicated that the **Central Valley (SR-99) Corridor** is well suited for serving both end-to-end and intermediate markets. With travel times between Los Angeles and the San Francisco Bay Area only slightly greater than those for the I-5 Corridor, the SR-99 Corridor also directly serves intermediate markets such as Fresno, Bakersfield, Modesto, Tracy/Stockton, Palmdale, and Lancaster. Population projections show that much of California's growth over the next 25 years will occur in these intermediate markets. By the year 2020, the Central Valley will be home to well over a million more residents than the Coastal Corridor, and three to four million more than the I-5 Corridor.

The **Interstate 5 (I-5) Corridor** best serves the end-to-end markets (i.e., trips between the San Francisco Bay Area and Los Angeles). This Corridor offers the shortest distances, lowest capital costs, fastest travel times, and the highest initial overall ridership forecasts. However, the I-5 Corridor would clearly be the least attractive corridor for serving intermediate markets and is the least compatible corridor with existing and planned development (largely because there is virtually no development along most of this Corridor). For the shortest I-5 route option, Kern County would be served by a station about 20 miles from downtown Bakersfield, while a Fresno County station would be about 46 miles from downtown Fresno.

The **Coastal Corridor** has the least potential for high-speed rail service at maximum speeds exceeding 150 mph. While the Coastal Corridor has the highest population living within a 10 mile wide strip, travel times between Los Angeles and the San Francisco Bay Area would be significantly longer than those of the other two corridors (43 percent to 97 percent longer than the shortest I-5 Corridor option). With significantly longer travel times, the projected ridership for this Corridor is considerably lower (24 percent to 46 percent lower than the shortest I-5 Corridor option). Moreover, this Corridor has the highest projected capital costs (24 percent higher than the shortest I-5 Corridor option) due to environmental constraints. The primary attraction of the Coastal Corridor is its ability to serve intermediate markets and locations such as Santa Barbara, Salinas/Monterey, San Luis Obispo, Ventura/ Oxnard, and the Simi Valley. In addition, the locations served are some of California's most popular tourist or recreational markets.

The Phase 1 evaluation concluded that detailed technical analysis for VHS or Maglev service should focus on the Central Valley (SR-99) and I-5 Corridors. The Coastal Corridor is best suited for service at speeds below those examined for this study and does not support travel times fast enough to capture a significant share of the end-to-end market. However, the intermediate locations served by the Coastal Corridor are popular tourist or recreation markets with sizable existing populations. These markets might be well served by a slower, relatively inexpensive service utilizing existing rail infrastructure.

Phase 1 findings were presented to the Intercity High Speed Rail Commission in May 1995. Based on these findings and the preliminary ridership forecasts, the Commission moved to focus further study on the I-5 and Central Valley (SR-99) Corridors. At this point, the Commission also directed that the planned high-speed rail system be capable of supporting maximum operating speeds of at least 200 mph, shifting the focus of the studies to the VHS and Maglev technology groups.

Phase 2 Summary

Phase 2 involved a more comprehensive evaluation of the I-5 and Central Valley (henceforth called SR-99) Corridors. Particular emphasis was given to mountain passes and alternative routes in Los Angeles and the Bay Area. The engineering analysis evaluated segments in greater detail with regard to conceptual plan and profile drawings, capital costs, and operations and maintenance costs. An environmental analysis identified potential impacts and constraints along the corridors.

The Phase 2 analysis concluded that although the SR-99 Corridor options are somewhat more costly than the I-5 Corridor options, the SR-99 Corridor offers far better service to the growing Central Valley population, while offering fast, competitive service between the Los Angeles and San Francisco Bay Area metropolitan regions. The SR-99 Corridor has the highest overall ridership potential. Furthermore, testimony at Commission meetings and at public workshops indicated overwhelming public support for the SR-99 Corridor.

The Phase 2 analysis also indicated that a southern terminus at Los Angeles Union Station was preferable to a terminus at Los Angeles International Airport (LAX). A southern terminus at Union Station results in higher ridership and farebox revenues and lower capital, operating, and maintenance costs; has greater public support; and facilitates extensions to San Diego via Orange County and San Bernardino/Riverside.

The Phase 2 environmental evaluation findings were presented to the Commission in December 1995 and the engineering evaluation findings in February 1996. Following the February presentation, the Commission moved to focus further study on the SR-99 Corridor. The Commission also decided that Union Station would be the most effective Los Angeles terminal location, concluding that the means of connecting a potential LAX Station with Union Station should be considered as an extension from downtown Los Angeles.

Phase 3 Summary

Phase 3 involved analysis of alignment options for extensions to Sacramento and San Diego to the same level and depth as in Phase 2. This phase provided important cost and impact information for the various alignments studied but did not lead the Commission to recommend alignment alternatives for the extensions.